SUNNYSIDE GOLD CORPORATION
AN ECHO BAY COMPANY

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August 20, 2002

Wally Erickson, Reclamation Specialist
Department of Natural Resources
Division of Minerals and Geology
Durango Field Office
701 Camino del Rio, Room 125
Durango, CO 81301

RE: File No. M-77-378, TR-25
American Tunnel Bulkhead No.2
Construction Certification Report

Dear Mr. Erickson:

This letter report is to provide certification that construction of the American Tunnel near-surface bulkhead meets or exceeds design criteria. Submittal of a construction certification report was committed to by SGC in TR-25 and required as a Stipulation for TR approval..
Pre-pour inspections were conducted by DMG and the design engineer, John F. Abel, Jr. P.E. on August 17, 2001 (letter report attached). No deficiencies were found in either pre-pour inspection.

Bulkhead location

The approximate center of the bulkhead, approximately five feet above the sill, on the air-side face (side towards surface) of the bulkhead is a point with coordinates of 12,795.54 N, 12,801.24 E at an elevation of 10,611.6 feet. These coordinates are based on a coordinate system with USLM Moultrie being at coordinates 11,964.00 N, 20,000.00 E at an elevation of 12,728.73 feet.

The construction stages for certification are listed below.

Bulkhead Buffer - Lime Placement

Three tons of hydrated lime were placed at the downstream face of Bulkhead No.1 and three tons were placed between the cofferdam and upstream face of Bulkhead No.2. In addition, an additional two tons were placed in a dry area approximately 5000' in-bye to provide additional buffering as the water level rose and filled the area between bulkheads. An initial low pH reading, obtained as the drift was starting to fill, prompted the pumping of an additional one ton of hydrated lime, in slurry, through the bulkhead to neutralize the rising water, leaving the hydrated lime at the bulkheads for long term protection.
The initial low pH resulted from exposure of the fault water (normal pH near 6) to a long-term accumulation of oxidized pyrite in the tunnel. Once neutralized and placed under water, the pyrite exposed along the tunnel surface area will not continue to oxidize at a significant rate due to a lack of oxygen. Based on pH and sulfate monitoring (information attached), Sunnyside has provided excess buffering to the system, as intended, and pH is higher and sulfate levels lower than would be expected if the system eventually equilibrates at ambient quality of the fault water.
The bulkhead was designed and constructed for severe pH and sulfate exposure while the anticipated exposure would be expected to be moderate (fault water quality). The exposure conditions indicated by the monitoring results would be considered minor with no risk of deterioration or shortened life from this level of exposure.

Bulkhead location preparation (scaling and washing)

The bulkhead site was scaled clean of loose material and sandblasted to remove any surface coating that may have been present. It was then washed down and vacuumed clean of water, sand and rock residue. This stage of site preparation was adequate to maximize the potential for bonding between the rock and the concrete bulkhead and was also inspected by the design engineer, John F. Abel, Jr., and DMG during their respective pre-pour inspections.
Removal of fractured rock resulted in a height that exceeded the original design assumption although the width (the critical design dimension) was somewhat less than the design width. In order to check the validity of the design, John Abel Jr., the design engineer, was asked to check the design using actual dimensions. His report, attached, verified the original design and allowed placement of downstream rebar at a 6.5" spacing instead of the original 6" spacing because of the narrower width.

By-pass or diversion pipe

The diversion pipe through the bulkhead is a 8" Schedule 40 - stainless steel pipe fitted with one thrust collar (3/8" thick – 2" larger in diameter than the pipe) and two light gauge seep collars. The thrust collar was placed at a distance of greater than 5' from the downstream face to allow any loads to be distributed to the tunnel walls. Two seep collars were placed, upstream and downstream of the thrust collar, to minimize the ability of impounded water to travel along the outside of the pipe. Bars were welded inside the pipe (upstream side) to provide a stop for the grout pig to simplify grouting the pipe full upon completion of the bulkhead. The pipe entrance was extended upstream to a temporary cofferdam, placed to keep the bulkhead area dry during construction. The pipe system was adequate to keep the area dry until after the concrete had sufficient time to cure.

The outlet end of the by-pass pipe was equipped with a stainless steel gate valve. Downstream of the gate valve, a pig launcher chamber was placed for use during final pipe grouting and closure. This launcher was equipped with a pressure monitoring gauge and sample pipe for monitoring as required under the stipulations for approval.

Construction of concrete forms and erection of rebar cages

The forms were constructed of vertical 8"x8" S4S posts and horizontal 2"x12" and 2"x6" S4S lagging. The form interior was lined with ¾" plywood for additional strength. Bracing consisted of angle iron and pipe anchored to the ribs, sill and back of the drift. The form construction and bracing was adequate to prevent movement or failure during filling of the forms.

The rebar cages were supported by dowels (rebar) grouted into the rib. The upstream rebar cage is #10 bars on a 6.5"x6.5" grid and the downstream rebar cage is #10 bars on a 6"x6" grid. The minimum clear distance from the form to the rebar is 3.5". The minimum bulkhead length was specified to be 10' and the actual length was 10'1". Trim bars (5' long) were placed at 45^0 to the rebar around the cutouts in the rebar cage for the pipe. All minimum clearances, dimensions and spacings met design criteria and were inspected by the design engineer prior to filling of the forms.

Perimeter area irregularity

The rock contact perimeter area irregularity required to develop the design compressive strength of the concrete when subject to the maximum design thrust was determined to be 8.3% of the area with a projection of 0.16" or more.
Quantification of a minimum perimeter area irregularity was accomplished by measuring x-sections within the bulkhead length and using the generated x-sections to quantify intrusive area as a percentage of the total area between sections. A summation of the individual areas between x-sections was used for quantification of the total percentage of intrusive area within the bulkhead.
This method provided an estimate of rock area irregularity of 44.1% which exceeds the design minimum of 8.3%. Attached to this report are the x-sections and table generated to quantify that this requirement was met.

Pumping of concrete, filling of forms and concrete compressive strength

The same concrete mix that proved successful for the American Tunnel Bulkhead No.1 was used for this bulkhead.
The concrete mix was as follows:

	#/cu. yd.
Portland Type II	720
Coarse Aggregate	1673
Fine Aggregate	1004
Fly Ash, Class F	115
Water	324
Delay Set	

The concrete was batched from the portable Sandco batch plant that was set up in Silverton. This is the same plant and concrete supplier used for the American Tunnel Bulkhead No.1 pour. The concrete pump was set up downstream of the bulkhead form and concrete was pumped approximately 30' to fill the bulkhead form. The concrete was hauled to the bulkhead from surface in 6 cubic yard Moran cars where it was remixed before discharge into the concrete pump and pumped into the form.
The bulkhead was poured on August 23, 2001 with the first truck arriving around 9:00 a.m.. The bulkhead form was determined to be full at approximately 6:00 a.m. on August 24th.

A set of concrete test cylinders was taken for approximately every 6 cu. yds. placed in the bulkhead form. The test cylinders were cured on-site. Break tests were performed at 7 days and 28 days to verify that the 3000 psi design strength was met or exceeded. The average 7 day strength obtained from the break tests was 3335 psi and the average 28 day strength obtained from the break tests was 4837 psi, well in excess of the required 3000 psi. All 28 day samples exceeded the 3000 psi compressive strength required by design, therefore no additional testing was planned or done. The test reports are attached.

Low pressure grouting of the concrete-rock contact

After construction of the air-side bulkhead form and placement of rebar, the form was marked for drillhole collars by nailing faucet washers to the form at the selected locations. One ring consisting of nine holes was drilled to intersect the rock contact along the perimeter at approximately the mid-point or center of the bulkhead. The target points were selected and then appropriate corresponding collar points were selected such that the hole could physically be drilled without hitting the rebar mat. Angles and distances were measured so the selected lines could be reproduced after the bulkhead form was stripped.
The bulkhead was drilled and the contact was low pressure grouted on August 30, 2001. Each hole was pressured to 200+ psi with very little grout take. The pressure applied to the formed bulkhead appears to have been adequate to fill the contact fractures.
The valve was closed on August 31st to stop the water and allow pressure to start building on the bulkhead to determine if additional grouting might be required. On September 13-15, 2001 additional low pressure grouting was successfully completed, minimizing seepage that increased under pressure along the contact area.

Monitoring

As required in the Stipulations for approval, pressure on the bulkhead was monitored until the definition of equilibrium was reached at 175 psi. This pressure is well below the design pressure of 277 psi. The monitoring results and a graph are included with this report.

Sulfate levels and pH of the water impounded behind the bulkhead were also monitored as required in the Stipulations for approval to provide assurance that the chemistry of the water will not deteriorate the bulkhead concrete. The pH and sulfate levels remained well

below the severity exposure that the concrete mix was designed for. This information is attached.

The American Tunnel Bulkhead No.2 construction meets or exceeds all design specifications.

Sincerely,

Larry Roger Perino, P.E.
Colorado Registration #24138

American Tunnel Bulkhead No.2
Perimeter Area Irregularity

Station	P	P_{ave}	D	P_0	DxP_0	$P_{ave}xD$
0+21.5	50.0					
		49.5	3.5	23.0	80.5	173.25
0+18.0	49.0					
		48.0	3.1	19.0	58.9	148.80
0+14.9	47.0					
		48.0	3.6	22.0	79.2	172.80
0+11.3	49.0					
			--------		--------	--------
TOTALS			10.2		218.6	494.85

For the perimeter area between Section 0+11.3 and Section 0+21.5

Perimeter Area Irregularity = 218.6/494.85 = 44.1%

The perimeter area irregularity of 44.1% is greater than the 8.3% required to develop the design strength of the bulkhead.

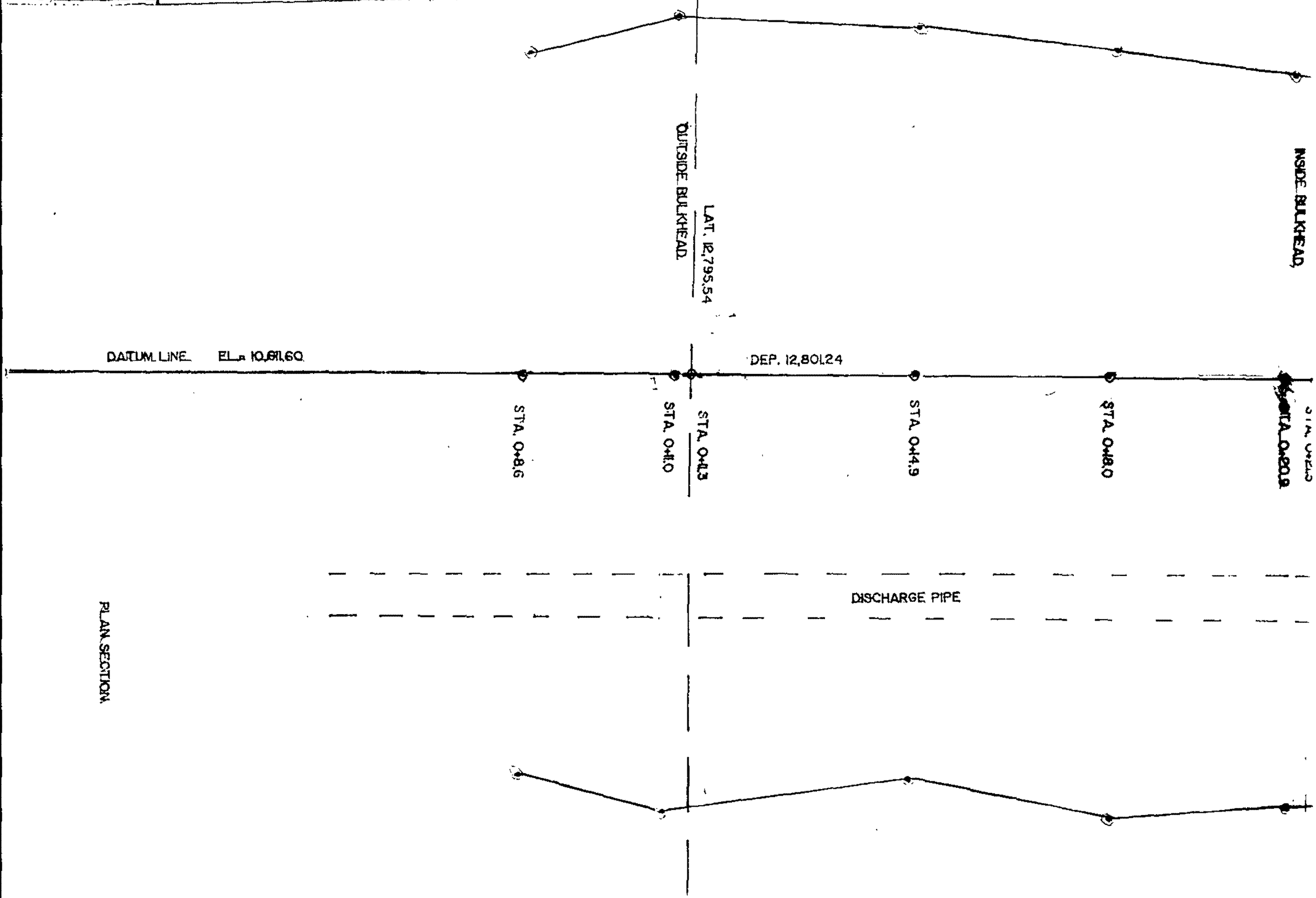
AUG. 10, 200

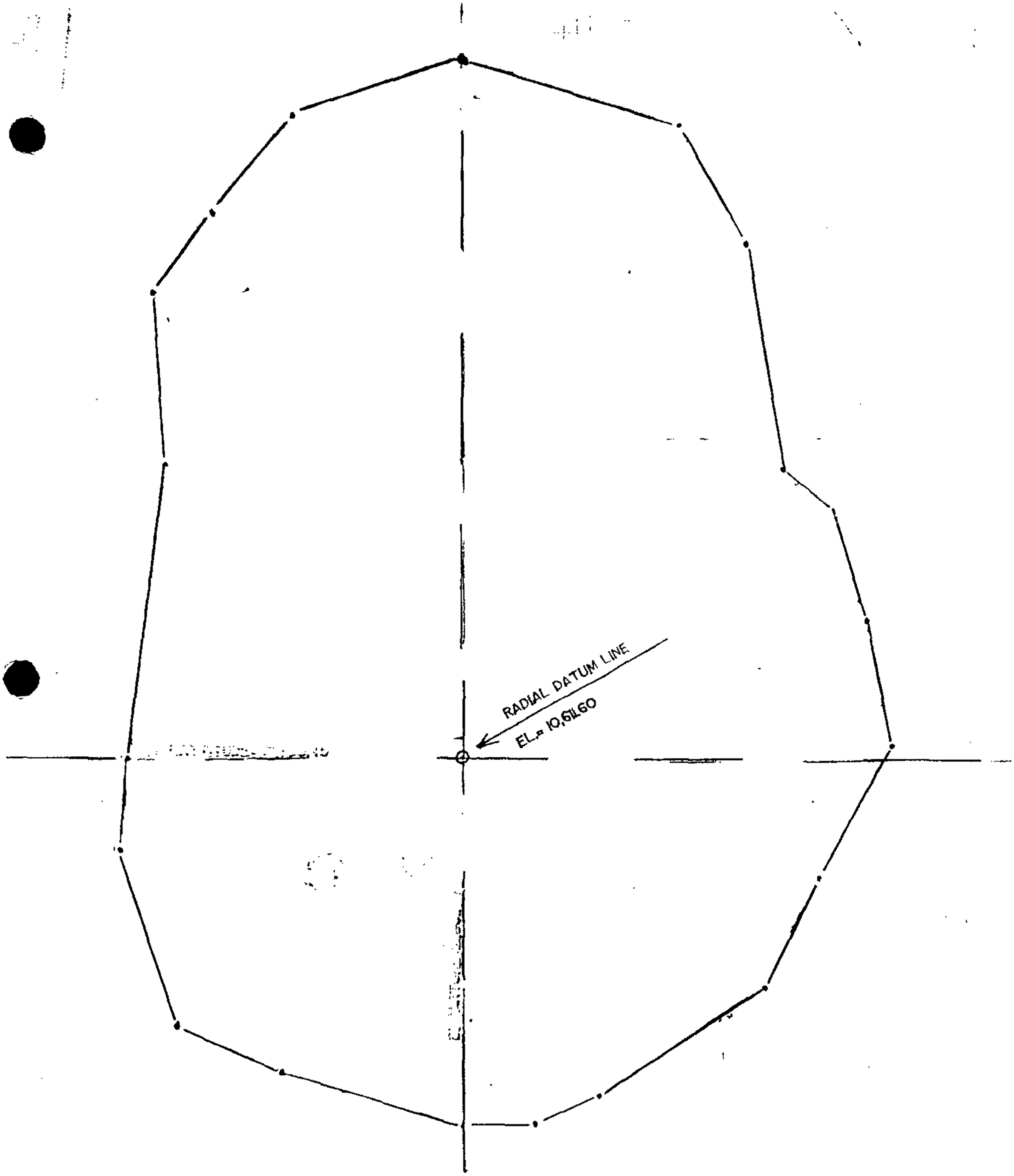
SUNNYSIDE GOLD CORPORATION

SILVERTON, COLORADO

AMERICAN TUNNEL BULKHEAD NO. 2

SCALE : 1 IN. = 2 FT.

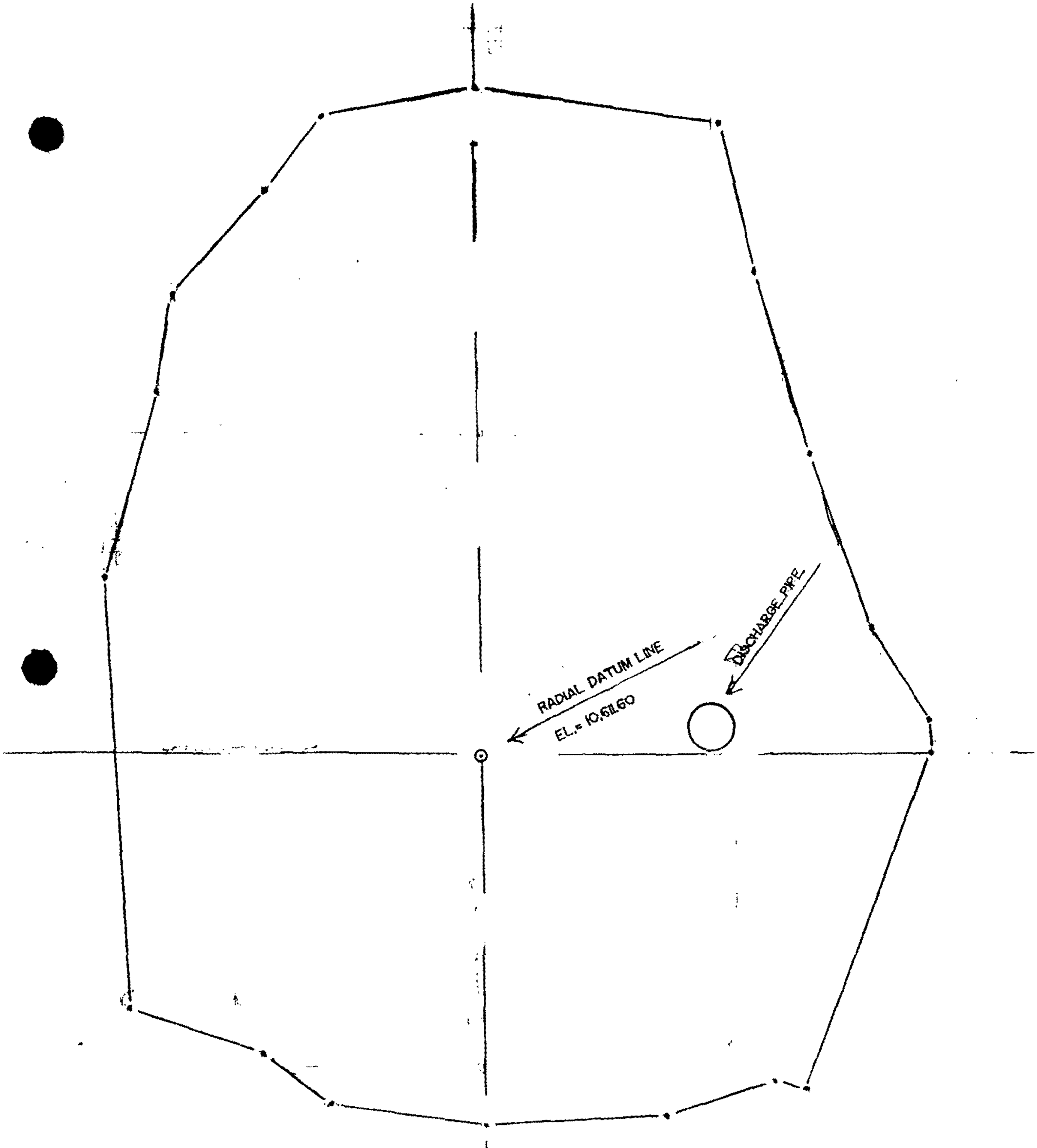




CROSS SECTION 0+8.60

AREA=151 SQ.FT.

DRAWN BY: GR TRACED BY: DATE AUG.10, 2001 CHECKED BY: REFERENCES:	SUNNYSIDE GOLD CORPORATION	SUNNYSIDE MINE AMERICAN TUNNEL BULKHEAD NO. SCALE : 1 IN. = 2 FT.



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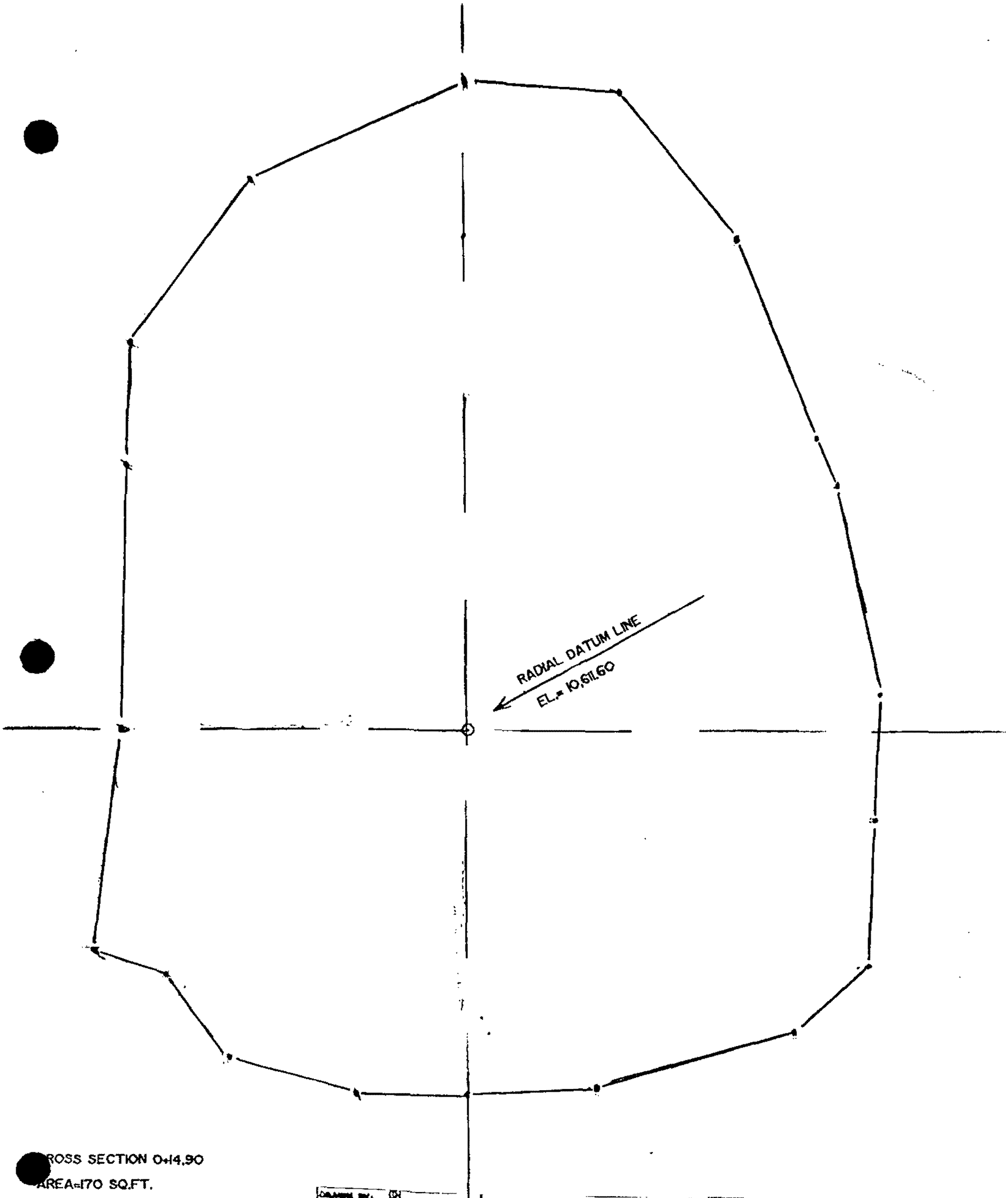
REFERENCES:

SUNNYSIDE GOLD CORPORATION

SUNNYSIDE MINE
AMERICAN TUNNEL BULKHEAD NO. 2

SCALE : 1 IN. = 2 FT.



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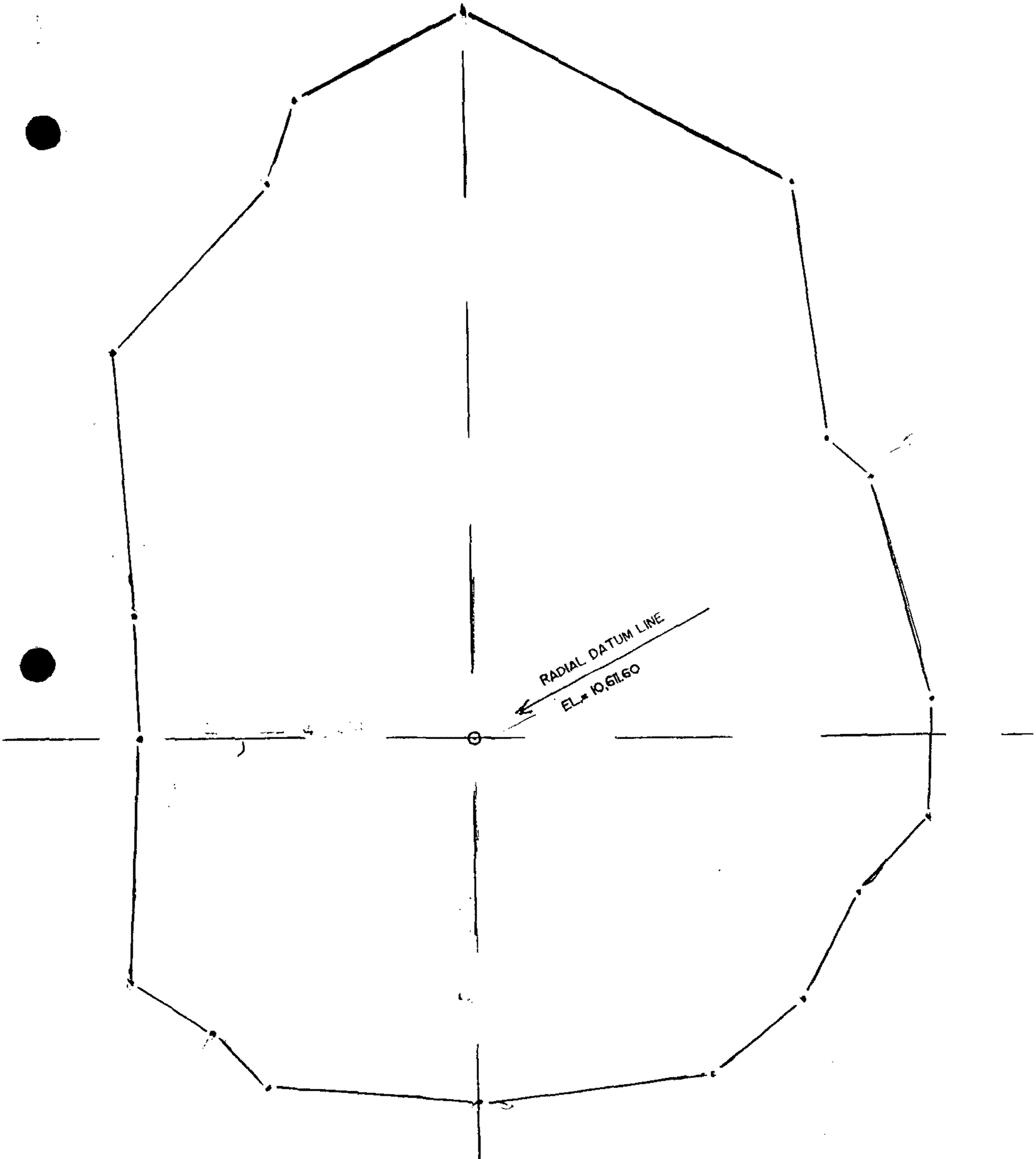
REFERENCES:	

SUNNYSIDE GOLD CORPORATION

SUNNYSIDE MINE
AMERICAN TUNNEL BULKHEAD NO. 2

SCALE : 1 IN. = 2 FT.



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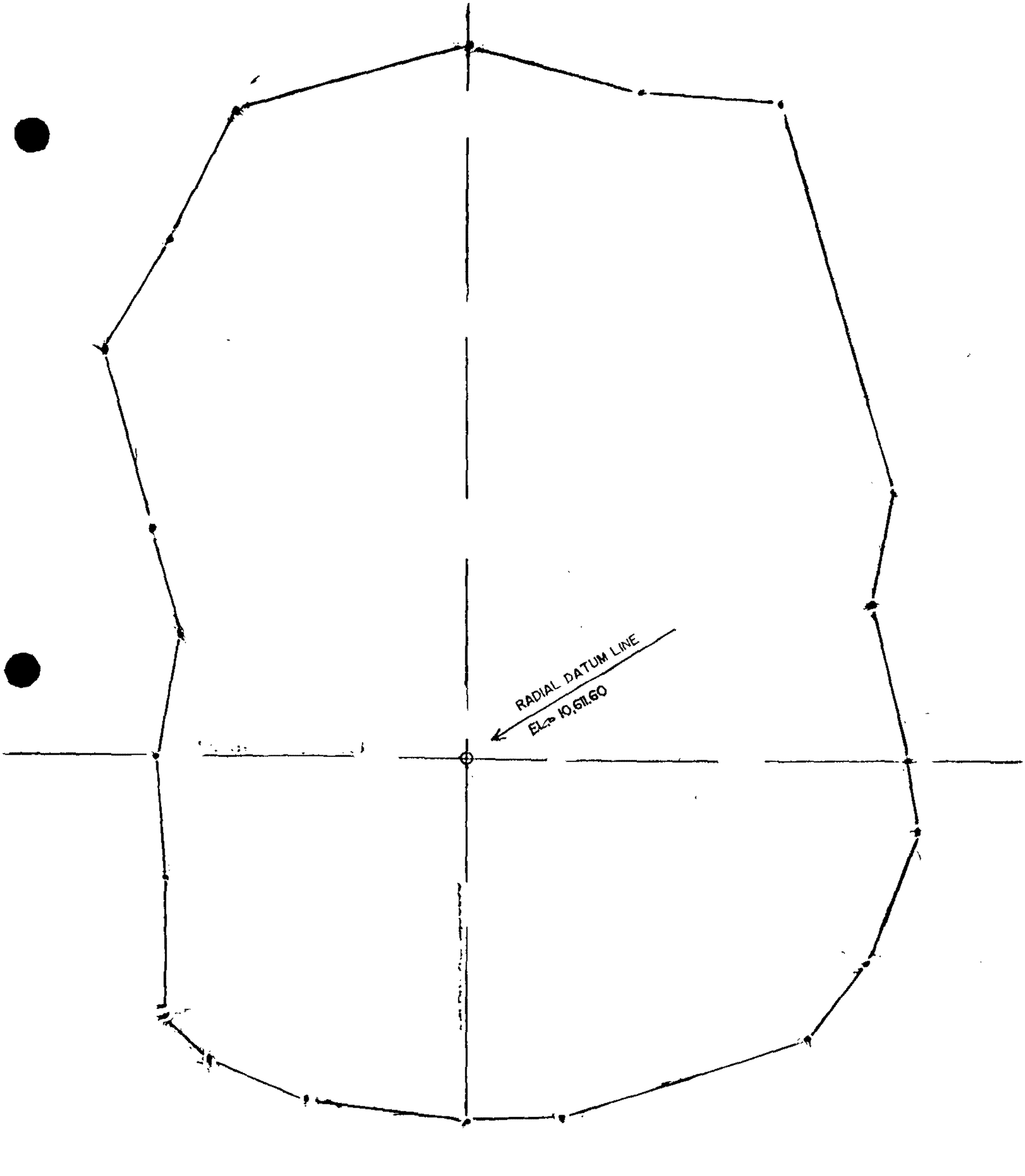
DATE:	AUG. 10, 2001
CHECKED BY:	
REFERENCES:	

SUNNYSIDE GOLD CORPORATION

SUNNYSIDE MINE
AMERICAN TUNNEL BULKHEAD NO. 2

SCALE : 1 IN. = 2 FT.



CROSS SECTION 0+20.9
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DRAWN BY: GN TRACED BY: DATED: AUG. 10, 2001 CHECKED BY: REFERENCE:	SUNNYSIDE GOLD CORPORATION	SUNNYSIDE MINE AMERICAN TUNNEL BULKHEAD NO. 2 SCALE : 1 IN. = 2 FT.

JOHN F. ABEL, JR.
MINING ENGINEER

310 LOOKOUT VIEW COURT
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303-279-4901
FAX 278-8163
JFAbel2@Home.com

August 20, 2001

Mr. Larry Perino
Sunnyside Gold Corp.
P.O. Box 177
Silverton, CO 81433

Dear Larry:

This is the letter report you requested concerning my inspection on August 17, 2001 of the completed preparations for filling the second American Tunnel Bulkhead at approximately Station 20+00. The bulkhead forms and the rebar installed equal or exceed the designs detailed in both my January 15, 2001 letter report and my July 27, 2001 redesign letter report necessitated by the dimension change found during excavation at the actual bulkhead location. The height of the American Tunnel at the bulkhead location had increased from 14-ft to 17-ft, apparently the result of increased overbreak in the floor. The nominal 13.5-ft design width of the tunnel is greater than the actual measured maximum 13.1-ft tunnel width at the bulkhead location. The maximum tunnel width I was able to measure during my inspection was 12.9-ft. I inspected the bulkhead for 1) the thickness of the bulkhead form, 2) the spacing and location of the bars, 3) the irregularities present on the back ribs and floor, 4) the soundness of the exposed rock, 5) the cleanliness of the bulkhead area and 4) the thrust collar and water stops on the bypass pipe.

I arrived at the bulkhead location at 9:20 a.m. and entered the bulkhead for the inspection. The bulkhead will occupy a length of 10 feet 1 inch, 1 inch longer than specified. The rebar cages were constructed as designed. The #10 horizontal bars had been tied into the downstream cage at the minimum 3.5 inches from the bulkhead forms. Installation of the #10 vertical bars was nearing completion at the time of my inspection. The downstream #10 tension bars were on 6-inch centers, as originally specified. The changed tunnel dimensions would have permitted an increase in bar spacing to 6.5-inches. Installation of the final three horizontal and three vertical bars had not been tied into the downstream cage in order for final access, cleaning and inspection prior to filling. These bars were hanging below the access and inspection hole, ready for installation when the concrete pour reaches that elevation. The #10 tension bars had been tied into the upstream cage at the minimum 3.5 inches from the bulkhead forms. The

upstream #10 tension bars were on 6.5-inch centers, as specified. Tensile reinforcement is necessary at the upstream face to resist the maximum credible earthquake acceleration of the line of site water that will be impounded by the third American Tunnel bulkhead, between approximately Station 3+67 and Station 3+82. The rebars had been individually cut to fit, no splices used in either rebar cage.

Removal of loose rock from the tunnel roof and walls has resulted in a saw-toothed bulkhead. The shape of the rock adjacent to the bulkhead is excellent for resisting movement under the design hydraulic thrust. The lower four feet of the latite porphyry in the bulkhead area is more tightly jointed than the overlying latite porphyry. As we discussed the fracture permeability in the lower section of the bulkhead may require low pressure grouting, if leakage develops during water impoundment. The pump installed outside the downstream form should provide a check on water leakage through the lower closely jointed tunnel rock after the valve is closed.

A few gallons of water was present at low spots in the floor of the bulkhead section. It will be necessary to remove as much of this water as possible immediately before filling.

One thrust collar and two water stops are installed on the bypass pipe. Trim bars were tied into each rebar cage where the bypass pipe passes through the rebar.

Filling of the form should proceed as soon as possible.

Sincerely,

John F. Abel, Jr.

John F. Abel, Jr.
Colorado P.E. 5642

JOHN F. ABEL, JR.
MINING ENGINEER

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July 27, 2001

Mr. Larry Perino
Sunnyside Gold Corp.
P.O. Box 177
Silverton, CO 81433

Reference: American Tunnel #2 bulkhead redesign

Dear Larry:

This is the letter report you requested for the redesign of the #2 bulkhead for the American Tunnel. The redesign was necessitated by changes in the measured tunnel dimensions during construction. The height of the tunnel at the #2 bulkhead increased from 14-ft to 17.2-ft after excavating the fill in the floor. The tunnel width decreased slightly from 13.5-ft to 13.1-ft when measured after the bulkhead location preparation was completed.

The bulkhead #2 calculations are provided in Appendix A. The overall result of these changes are to specify a 10-ft thick bulkhead with #10 bars on 6.5-in centers as a single two-way cage at both faces of bulkhead #2. The controlling factor for the tensile reinforcement at the upstream face is the predicted earthquake loading from the 1630 feet of line-of-sight water that will be impounded downstream after bulkhead #3 is constructed. The tensile reinforcement at the downstream face is required to resist the flexural bending from the potential pressure head from the water impounded between bulkhead #2 and bulkhead #1, already installed.

Sincerely,

John F. Abel, Jr.

John F. Abel, Jr.
Colorado P.E. 5642

Appendix A. American Tunnel #2 bulkhead redesign calculations

Notation:

a = compression zone depth(in) minimum to balance rebar tension

A_s = area of rebar

b_w = web width (12 in)

C = comp bending force (lb)

D = dead load $\left(\frac{lb}{ft}\right)$

E = earthquake load $\left(\frac{lb}{ft}\right)$

E_m = earthquake mass $\left(\frac{lb\text{-}sec^2}{ft}\right)$

F = fluid load $\left(\frac{lb}{ft}\right)$

f'_c = concrete comp strength (3,000 psi)

f_{ct} = concrete tensile strength $\left(5\phi\sqrt{f'_c}\ \text{psi}\right)$

f = rebar yield strength (60,000 psi)

H = design water head (640 ft)

I = moment of inertia

L = bulkhead (beam) thickness

M = bending moment (ft·lb)

M_u = factored beam moment (ft·lb)

m_c = minimum cover, form face to rebar surface (3.5 in)

S_{lo} = outbye line-of-sight distance (1630 ft)

U = required strength $\left(\frac{lb}{ft}\right)$

V_c = concrete shear strength (lb)

V_s = rebar shear strength (lb)

v_s = rebar shear stress (psi)

ω = uniform load $\left(\frac{lb}{ft}\right)$

ρ = pressure head (203 psi)

$\rho_w = \frac{A_s}{b_w d}$

γ_w = water density (62.4PCF)

γ_c = concrete density (151PCF)

γ_r = rock density (173 PCF)

σ_s = flexure stress (psi)

Z = bulkhead design depth (115 ft)

b = beam width (1 ft)

Bp = formation breakdown pressure (psi)

c = centroidal distance (in)

d = distance, extreme compression fiber to rebar centroid (in)

ΣE = total earthquake load (lb)

FS = factor of safety

$\sqrt{f'_c}$ = square root of f'_c

f'_s = concrete shear strength (psi)

g = acceleration due to gravity $\left(32.2\ \frac{ft}{sec^2}\right)$

h = tunnel height (17.2 ft)

$K = \left(3.5 - 2.5\frac{M_u}{d}\right)$

ℓ = tunnel width (13.1 ft)

M_n = nominal beam moment (ft·lb)

M_{ua} = earthquake beam moment (ft·lb)

S = section modulus (in^3)

S_{li} = inbye line-of-sight distance (1280 ft)

T = tensile bending force (lb)

U_a = earthquake required strength

V_n = nominal shear force (lb)

V_u = factored shear force (lb)

W = total bulkhead load (lb)

a = earthquake acceleration $\left(0.087\frac{ft}{sec^2}\right)$

ρ_g = pressure gradient $\left(\frac{psi}{ft}\right)$

ϕ = strength reduction factors

- 0.90 flexure rebar tension
- 0.85 concrete shear
- 0.65 plain concrete flexure

ω = uniform bulkhead design load

Load factors (ACI 318, Sec 9.2.2, 9.2.3, 9.2.5)

Static fluid load factor (F) = 1.4;
Factor for fluid load under earthquake acceleration (F) = 1.05;
Earthquake accelerated load factor (E) = 1.40

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

Hydraulic pressure gradient for 10-ft thick bulkhead:

Low pressure grouting of concrete-rock contact but not rock, gradient allowable = 41 psi/ft (Garrett & Campbell-Pitt, 1958, Chekan, 1985, p11), with factor of safety of 4

American Tunnel #2 bulkhead, maximum pressure head

$$\rho = \frac{H\gamma_w}{144} = \frac{640(62.4)}{144} = 277 \text{ psi}$$

Required bulkhead length with low pressure grouting on concrete/rock bulkhead contact:

$$\mathbf{L} = \frac{\rho}{41} = \frac{277}{41} = \mathbf{6.76\ ft}$$

Pressure gradient with L = 10 ft $\rho_g = \frac{\rho}{L} = \frac{277}{10} = 27.7$ psi/ft

Factor of Safety against water leakage along concrete/rock contact around 10-ft thick bulkhead is:

$$\underline{\mathbf{FS}} = \frac{41}{27.7} = \underline{\mathbf{1.41}}$$

American Tunnel #2 bulkhead depth below surface (Z) required to prevent hydrofrac of rock around tunnel by 640-ft hydraulic head (277 psi pressure head): (Einarson & Abel, 1990)

$$B_p = 3\sigma_{min} - \sigma_{max} = 2\sigma_{ovb} = 2Z(\frac{\gamma_r}{144}) = 2Z(\frac{173}{144}) = 2.403Z \text{ psi} = 277 \text{ psi}$$

$$\underline{\mathbf{Z}} = \frac{277}{2.403} = \underline{\mathbf{115\ ft}}$$

Therefore, the planned location for the American Tunnel #2 bulkhead, between Station 19+96 ft and Station 20+20 inside the American Tunnel portal with a minimum overburden of 762 ft will not be subject to formation hydrofracturing.

Concrete shear on American Tunnel #2 bulkhead perimeter:

$f'_s = 2\sqrt{f'_c} = 2\sqrt{3000} = 110$ psi (ACI 318-95, Sec 11.3.1.1)

$$\mathbf{L} = \frac{\rho h \ell}{2(h+\ell)f'_s} = \frac{277(17.2)13.1}{2(17.2+13.1)110} = \frac{62410}{6666} = \mathbf{9.36\ ft}$$

$W = \rho h \ell = 277(17.2)13.1(144) = 8{,}988{,}000$ lb

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

$$v_s = \frac{W}{[2(h+l)]L(144)} = \frac{8988000}{[2(17.2+13.1)]10(144)} = \frac{8988000}{87260} = 103.0 \text{ psi}$$

$$\underline{\mathbf{FS}} = \frac{f_s'}{v_s} = \frac{110}{103.0} = \underline{\mathbf{1.07}}$$

Plain concrete deep beam bending stress design, American Tunnel #2 bulkhead (ACI 318-95, Sec 9.9.2.5, 18.4.1(b), & ACI 318-71, Sec 9.2.1.5)

American Tunnel #2 bulkhead, for 640-ft hydraulic head (277 psi pressure head):

$$\omega = U = 1.4p(144) = 1.4(277)144 = 55{,}840 \left(\frac{\text{lb}}{\text{ft}}\right)$$

$$M_n = \frac{\omega\ell^2}{8} = \frac{55840(13.1^2)}{8} = 1{,}198{,}000 \text{ ft·lb}$$

$$M_u = \frac{M_n}{0.65} = \frac{1198000}{0.65} = 1{,}843{,}000 \text{ ft·lb}$$

$$S = \frac{I}{c} = \frac{\frac{bL^3}{12}}{\frac{L}{2}} = \frac{\frac{1(L^3)(12^3)}{12}}{\frac{L(12)}{2}} = \frac{144L^2}{6}$$

$$f_{cl}' = 3\sqrt{f_c'} = 3\sqrt{3000} = 164 \text{ psi}$$

$$f_{cl}' = 164 = \sigma = \frac{M_u c}{I} = \frac{M_u}{S} = \frac{1843000}{\frac{144L^2}{6}} = \frac{76790}{L^2}$$

L = $\sqrt{\frac{76790}{164}} = \sqrt{468.2} =$ **21.6 ft**, length required for plain concrete bulkhead.

$$\sigma_s = \frac{M_u}{S} = \frac{M_u}{\frac{144L^2}{6}} = \frac{1843000}{\frac{144(10^2)}{6}} = \frac{1843000}{2400} = 768 \text{ psi}$$

FS = $\frac{f_{cl}'}{\sigma_s} = \frac{164}{768}$ = **0.21**

Therefore, a 10-ft long bulkhead must be reinforced.

Reinforced concrete deep-beam bending stress design, American Tunnel #2 bulkhead (ACI 318-95, Sec 9.3.2.3, Sec 9.3.2.3.: Wang & Salmon, 1985: Einarson & Abel, 1990)

$$C = \phi f_c' b_w = 0.85(3000)12a = 30600a$$

$$T = A_s f_y = 60000A_s$$

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

$C = T;$ $30600a = 60000A_s;$ $a = \frac{60000A_s}{30600} = 1.961A_s$

$\omega = U = 1.4\rho(144) = 1.4(277)144 = 55{,}840\left(\frac{lb}{ft}\right)$

$M_n = \frac{\omega\ell^2}{8} = \frac{55840(13.1^2)}{8} = 1{,}198{,}000$ ft·lb

$M_u = \frac{M_n}{0.9} = \frac{1198000}{0.9} = 1{,}331{,}000$ ft·lb (15,970,000 in·lb)

$M_u = A_s f_y(d - \frac{a}{2});$ $d = L - m_c = 10(12) - 3.5 = 116.5$ *in*

$M_u = 60000A_s(d - \frac{a}{2}) = 60000A_s\left(116.5 - \frac{1.961A_s}{2}\right) = 6990000A_s - 58830A_s^2$

Therefore: $16{,}940{,}000 = 6990000A_s - 58{,}830A_s^2$

$58{,}830A_s^2 - 6{,}990{,}000A_s + 15{,}970{,}000 = 0$

A_s= 2.330$\frac{in^2}{ft}$ steel area required for outbye (downstream) side of 10-ft thick bulkhead

#10 bars (1.270 in^2 per bar) on 6.5-in c-c provides 2.345 $\frac{in^2}{ft}$ steel area

Check for adequacy

Allowable $M_u = -58{,}830A_s^2 + 6{,}990{,}0000A_s = 16{,}070{,}000$ in·lb

Design Mu = 15,970,000 *in·lb*

<u>FS</u> = $\frac{16070000}{15970000}$ = **<u>1.01</u> for outbye (downstream) side of 10-ft thick bulkhead**

Critical section shear strength for American Tunnel #2 bulkhead, 10-ft thick deep-beam bulkhead

Deep beam defined as $\frac{\ell}{d} < 5$ (ACI 318-95, Sec 11.8.1). Critical section shear at 0.15l (1.90 ft) from ribside (ACI 318-95, Sec 11.8.5), with #10 bars on 6.5-in c-c, there will be 2.354 $\frac{in^2}{ft}$ of steel per ft of beam width, d = 116.5 in (9.71 ft).

Detailed shear strength at critical section (ACI 318-95, Sec 11.8.7)

$\frac{\ell}{d} = \frac{13.1(12)}{[10(12)-3.5]} = \frac{157.2}{116.5} = 1.35 < 5$ Therefore, reinforced concrete bulkhead is a deep beam for design!

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

v_n - nominal shear stress shall not be greater than $8\sqrt{f'_c}$ when $\frac{\ell}{d} < 2$
(ACI 318-95, Sec 11.8.4)

Limiting value: $v_n \le 8\sqrt{3000} \le 438$ psi $\quad V_n \le (v_n)b_w d \le (438)12(116.5) \le 612{,}300$ lb

$$V_n = \frac{\omega\ell}{2} - \left(\frac{\omega\ell}{2}\right)\left(\frac{0.15\ell}{0.5\ell}\right) = 0.35\omega\ell = 0.35(55830)13.1 = 256{,}000 \text{ lb}$$

$$V_u = \frac{V_n}{0.85} = \frac{256000}{0.85} = 301{,}200 \text{ lb}$$

$$M_n = \left(\frac{\omega\ell}{2}\right)(0.15\,\ell) - \omega(0.15\,\ell)\frac{0.15\ell}{2} = 0.06375\frac{\omega\ell^2}{2} = 0.06375\frac{[55830(13.1^2)]}{2}$$

$$M_n = 305{,}400 \text{ ft}\cdot\text{lb}$$

$$M_u = \frac{M_n}{0.9} = \frac{305400}{0.9} = 339{,}300 \text{ ft}\cdot\text{lb}$$

$$V_c = K\left(1.9\sqrt{f'_c} + 2500\rho_w\frac{V_u d}{M_u}\right)b_w d$$

$$K = 3.5 - 2.5\frac{M_u}{V_u d} = 3.5 - 2.5\left[\frac{339300}{301200\left(\frac{116.5}{12}\right)}\right] = 3.5 - 0.12 = 3.38$$

K cannot exceed 2.5 Therefore K = 2.5

$\rho_w = \frac{A_s}{b_w d} = \frac{2.345}{(12)116.5} = 0.001677$ Trial, #10 bars on 6.5-in centers, two-way

$$V_c = K\left(1.9\sqrt{f'_c} + 2500\rho_w\frac{V_u d}{M_u}\right)b_w d$$

$$V_c = 2.5\left[1.9\sqrt{3000} + 2500(0.001677)\frac{301200\left(\frac{116.5}{12}\right)}{339300}\right]12(116.5)$$

$$V_c = 2.5[104.1 + 36.1]1398 = 2.5[140.1]1398 = 489{,}600 \text{ lb}$$

Allowable $Vc \le \left(6\sqrt{f'_c}\right)b_w d \le (6\sqrt{3000})12(116.5) = 459{,}400$lb (ACI 318-95, Sec 11.8.7)

Therefore, <u>FS</u> $= \frac{V_c}{V_u} = \frac{459400}{301200} =$ **<u>1.53</u>**

Earthquake bulkhead design; Load factors (ACI 318-95, Sec 9.2.2, 9.2.3, 9.2.5): Factor for fluid load under earthquake acceleration (F) = 1.05; Load factor for earthquake accelerated mass (E) = 1.40. Maximum credible earthquake acceleration (a) is 0.087 $\frac{\text{ft}}{\text{sec}^2}$.

U = 1.05F + 1.40E

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

Loads to be carried by inbye (upstream) rebar of bulkhead resulting from maximum credible earthquake acceleration of the outbye fluid (F) and bulkhead (E) masses bearing on a 10-ft thick bulkhead.

$$E_m = \frac{S_{lo}\gamma_w h\ell + Lh\ell\gamma_c}{g} = \frac{[1630(62.4)17.2(13.1)+10(17.2)13.1(151)]}{32.2} = \frac{[22{,}920{,}000+340{,}200]}{32.2} = 722,400 \ \frac{\text{lb}\cdot\text{sec}^2}{\text{ft}}$$

$$\Sigma E_m = E_m a = 722{,}400(0.087) = 62{,}850 \text{ lb}$$

$$E = \frac{\sum E_m}{h} = \frac{628500}{17.2} = 3,654 \frac{\text{lb}}{\text{ft}}$$

Total load under maximum earthquake acceleration for American Tunnel #2 bulkhead, under 773-ft hydraulic head:

$$\rho = \frac{H\gamma_w}{144} = \frac{773(62.4)}{144} = 335 \text{ psi}$$

$$F = \rho b_w(12) = 335(12)12 = 48{,}240 \ \frac{\text{lb}}{\text{ft}}$$

$$U_a = 1.05F + 1.40E = 1.05(48240) + 1.40(3654) = 50{,}650 + 5{,}120$$

$$U_a = 55{,}770 \ \frac{\text{lb}}{\text{ft}}$$

Earthquake nominal beam bending moment

$$M_{na} = \frac{U_a \ell^2}{8} = \frac{55770(13.1^2)}{8} = 1{,}196{,}000 \text{ ft}\cdot\text{lb}$$

$$M_{ua} = \frac{M_n}{0.9} = \frac{1196000}{0.9} = 1{,}329{,}000 \text{ ft}\cdot\text{lb } (15{,}950{,}000 \text{ in}\cdot\text{lb})$$

Steel area required for earthquake loading:

$$58830A_s^2 - 6{,}990{,}000A_s + 15{,}950{,}000 = 0$$

A_s= 2.327 $\frac{\text{in}^2}{\text{ft}}$ *Steel area required to resist maximum credible earthquake loading for* 10-ft thick bulkhead, i.e. the inbye (upstream) side of the bulkhead.

#10 bars on 6.5-in c-c provide 2.345 $\frac{\text{in}^2}{\text{ft}}$ steel area

Check for adequacy

$$\text{Allowable } M_{ua} = -58,830A_s^2 + 6,990,000A_s = 16,070,000 \text{ in}\cdot\text{lb}$$

$$\text{Design } M_{ua} = 15,950,000\text{in}\cdot\text{lb}$$

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

$\underline{FS} = \frac{16070000}{15950000} = \underline{1.01}$ for the inbye (upstream) side of the 10-ft thick bulkhead under maximum earthquake loading

Loads to be carried by outbye (downstream) side rebar of bulkhead resulting from maximum credible earthquake acceleration of the inbye fluid (F) and bulkhead (E) masses bearing on a 10-ft thick bulkhead.

$$E_m = \frac{S_{li}\gamma_w h\ell + Lh\ell\gamma_c}{g} = \frac{[1280(62.4)17.2(13.1)+10(17.2)13.1(151)]}{32.2} = \frac{[18{,}000{,}000+340{,}000]}{32.2} = 569,600\ \frac{\text{lb-sec}^2}{\text{ft}}$$

$$\Sigma E_m = E_m a = 569{,}600(0.087) = 49{,}560\ \text{lb}$$

$$E = \frac{\Sigma E_m}{h} = \frac{49560}{17.2} = 2,881\,\frac{\text{lb}}{\text{ft}}$$

Total load under maximum earthquake acceleration for American Tunnel #2 bulkhead, under 640-ft hydraulic head:

$$\rho = \frac{H\gamma_w}{144} = \frac{640(62.4)}{144} = 277\ \text{psi}$$

$$F = \rho b_w(12) = 277(12)12 = 39{,}890\ \frac{\text{lb}}{\text{ft}}$$

$$U_a = 1.05F + 1.40E = 1.05(39890) + 1.40(2881) = 41{,}880 + 4{,}030$$

$$U_a = 45{,}910\ \frac{\text{lb}}{\text{ft}}$$

Earthquake nominal beam bending moment

$$M_{na} = \frac{U_a \ell^2}{8} = \frac{45910(13.1^2)}{8} = 984{,}800\ \text{ft}\cdot\text{lb}$$

$$M_{ua} = \frac{M_n}{0.9} = \frac{984800}{0.9} = 1{,}094{,}000\ \text{ft}\cdot\text{lb}\ (13{,}130{,}000\ \text{in}\cdot\text{lb})$$

Steel area required for earthquake loading:

$$58800A_s^2 - 6{,}990{,}000A_s + 13{,}130{,}000 = 0$$

$A_s = 1.909\ \frac{\text{in}^2}{\text{ft}}$ *Steel area required to resist maximum credible earthquake loading for* 10-ft thick #2 bulkhead on the outbye (downstream) side of the bulkhead.

#10 bars on 6.5-in c-c provide 2.345 $\frac{\text{in}^2}{\text{ft}}$ steel area (required for flexural bending at downstream face)

Appendix A. American Tunnel #2 bulkhead redesign calculations (Continued)

Check for adequacy

Allowable $M_{ua} = -58,800A_s^2 + 6,990,000A_s = 16,070,000 \text{ in} \cdot \text{lb}$

Design earthquake $M_{ua} = 13,130,000 \text{in} \cdot \text{lb}$

FS $= \frac{16070000}{13130000} =$ **1.22 for the outbye (downstream) side of the 10-ft thick #2 bulkhead under maximum earthquake loading**

JOHN F. ABEL, JR.
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August 8, 2001

Mr. Larry Perino
Sunnyside Gold Corp.
P.O. Box 177
Silverton, CO 81433

Reference: Adequacy of 6-in rebar spacing, downstream form American Tunnel bulkhead #2 redesign dimensions

Dear Larry:

The 6-in rebar spacing that was originally planned for the #2 bulkhead for the American Tunnel (January 15, 2001 letter report) is adequate for the redesign dimensions at the bulkhead location (July 22, 2001 letter report). The original tunnel design dimensions between station 19+95 and station 20+20, the section of the American Tunnel chosen for the bulkhead #2 were 14-ft high by 13.5-ft wide. It is the tunnel width which is critical for the tensile rebar reinforcement to support the deep beam bending moment from the fluid load from the impounded water. The design method assumes that the bending moment is transferred from rib to rib because of the excellent contact bond between the concrete and the rock at the ribsides. The roof to floor bending resistance is not relied upon for design because the roof contact bond between the concrete and the rock relies on the concrete pumping pressure. This is also why the roof contact between the concrete and the rock is grouted after the bulkhead concrete sets. The maximum measured tunnel height within the 10-ft thickness of bulkhead #2 is 17.2-ft and the maximum tunnel width within the 10-ft thickness of the bulkhead #2 is 13.1-ft. These maximum bulkhead design dimensions were measured after the loose rock on the roof, ribsides and floor had been removed in the selected bulkhead location.

The bulkhead #2 calculations for the originally assumed 13.5-ft maximum tunnel width required 2.475 square inches of tensile reinforcement to resist the deep beam bending moment from the fluid load. The #10 bars on 6-in centers provides 2.540 square inches of tensile reinforcement (FS = 1.03). The bulkhead redesign for the measured 13.1-ft maximum tunnel width requires 2.330 square inches of tensile reinforcement to resist the deep

beam bending moment from the fluid load. The 2.540 square inches of tensile reinforcement provided by #10 bars on 6-in centers is obviously adequate (FS = 1.09).

As I indicated on page 5 of my July 27,2001 letter report, #10 bars on 6.5-in centers would provide 2.345 square inches of tensile reinforcement and would also be adequate (FS = 1.01).

Sincerely,

John F. Abel,

John F. Abel, Jr.
Colorado P.E. 5642

Sundale Associates, Inc.

Engineering & Testing

A WLC Associates, Inc. Company

SUNNYSIDE GOLD - SILVERTON COLORADO

TABLE OF CONCRETE TEST RESULTS (09-21-2001)

TEST NUMBER	POUNDS	PSI	28-DAY BREAK
1-B	151000	5340	YES
2-B	137000	4850	YES
3-B	150500	5320	YES
4-B	112000	3960	YES
5-B	115000	4070	YES
6-B	115000	4070	YES
7-B	135000	4780	YES
8-B	152500	5390	YES
9-B	150500	5320	YES
10-B	149000	5270	YES

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A WLC Associates, Inc. Company

SUNNYSIDE GOLD - SILVERTON COLORADO

TABLE OF CONCRETE TEST RESULTS (08-31-2001)

TEST NUMBER	POUNDS	PSI	7-DAY BREAK
1-A	84000	2970	YES
2-A	124500	4400	YES
3-A	108500	3840	YES
4-A	74000	2620	YES
5-A	81500	2880	YES
6-A	75000	2650	YES
7-A	91500	3240	YES
8-A	103500	3660	YES
9-A	108500	3840	YES
10-A	92000	3250	YES
		3335 Ave	

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